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US Army Research Laboratory

US Army Research Laboratory and University of Notre Dame Distributed Sensing: Hardware Overview

by Roger P Cutitta, Charles R Dietlein, Arthur Harrison, and Russell Harris

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14. ABSTRACT A distributed collaborative sensor and transmitter architecture was developed in support of an ongoing collaborative agreement between the US Army Research Laboratory (ARL) and the University of Notre Dame (UND). The hardware developed in support of this research effort was designed to provide a mobile ad hoc network (MANET) of diverse software-defined sensors to perform detection and geolocation of a signal source of interest. A transmitter module was designed using the same fundamental hardware as the sensor modules. The transmitter modules would provide a software-defined waveform and ground-truth location to the distributed collaborative network of sensor modules. ARL has designed and fabricated the sensors, emitters, and the MANET architecture to be used in conjunction with UND's custom software-defined sensors.			
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1. Summary

A research collaboration between the University of Notre Dame (UND) and the US Army Research Laboratory (ARL) has established a need for a testbed of multiple software-defined sensors and sources (SDSSs). ARL has developed a common back-end architecture to give researchers the ability to experiment and demonstrate different commercially available SDSS platforms, within a single network, to geolocate emitters. The ARL SDSS modules were successfully used at a field test by UND and ARL. The first field test using the ARL-designed back-end sensor and signal source hardware was successfully conducted at the UND's White Field test site 26–28 June 2017. This report outlines the ARL sensor and signal source node hardware design that was implemented.

2. Introduction

Two SDSS hardware personalities were implemented utilizing a common hardware architecture. The SDSS hardware was configured based on the personality it was to inherit for the experiments, either a sensor or a source. Commercial off-the-shelf (COTS) modules were integrated into the SDSS architecture. This enables rapid implementation and reconfiguration based on the desired SDSS module functionality. Minimization of size, weight, and power was a major goal during the design and implemenatation phases.

3. System Descriptions

The SDSS module hardware was implemented to enable rapid experimentation in spectrum sensing and geolocation research. A common network back-end, to connect and administrate each of the nodes in the network, was considered the first priority for the testbed development. The network enables the nodes to communicate with one another during experimentation.

A COTS mobile ad hoc network (MANET) system was chosen to allow flexibility of adding or subtracting SDSS nodes from the network and experiment. The MANET automatically optimizes routing among participating network nodes.

Figure 1 depicts a simple high-level example of the networked distributed sensor, target, and the data processing and network control (DPNC) module experiment that could detect and geolocate the emitting target module. Each of the sensor modules report back a received signal strength indicator (RSSI), which is representative of the detection range of the module or module cluster, to the DPNC.

The DPNC then processes each reported RSSI and the reporting module's location to determine the targets geolocation.

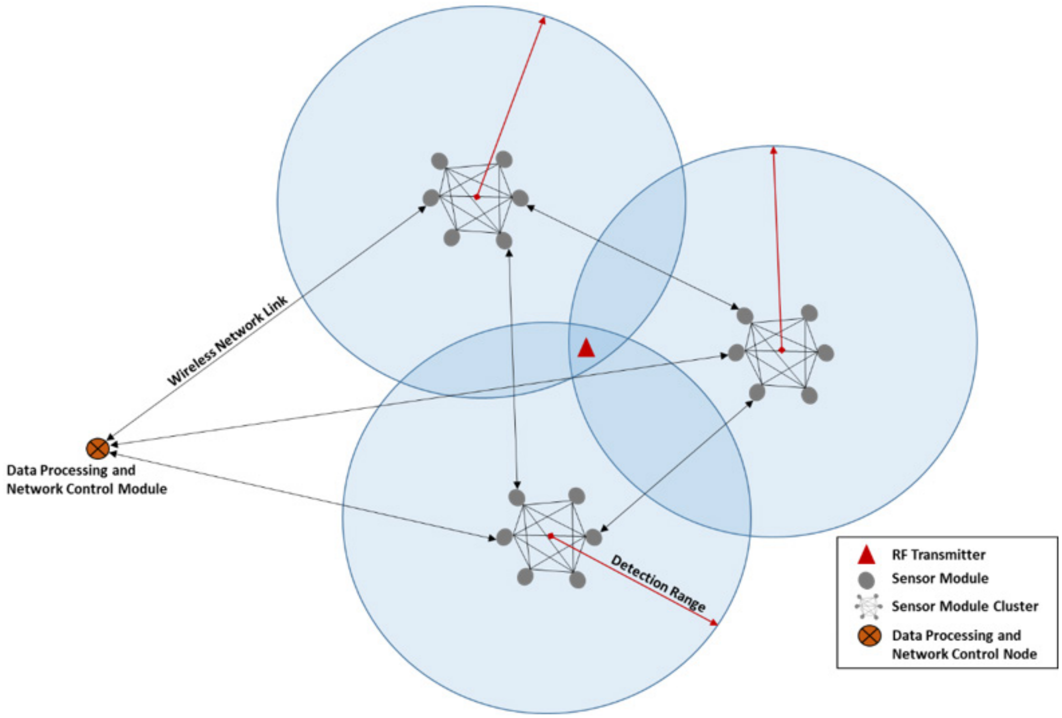

Fig. 1 Sensor and signal source experimental geolocation concept-of-operation example

3.1 MANET Back-end

ARL provided UND with 15 nodes with the integrated MANET back-end and internal power conditioning only. This allowed UND researchers to integrate their own software-defined radio (SDR) of choice while leveraging the ARL SDSS architecture and MANET. Figures. 2–4 show the outline of the enclosure and location of external interfaces. The block diagram, shown in Fig. 5, shows the MANET hardware and power conditioning. Figure 6 shows the custom ARL node power supply implementation.

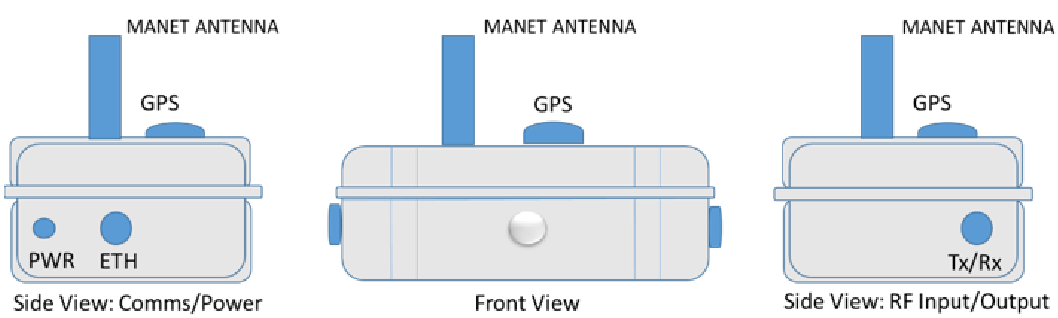

Fig. 2 Common ARL SDSS module antenna, power, and communication port locations

Fig. 3 Node exterior depicting the SDSS assembly including the GPS puck antenna, 2.4-GHz MANET antenna, and 5.8-GHz SDR antenna

Fig. 4 Node exterior depicting the 2-pin power connector and auxiliary Ethernet port

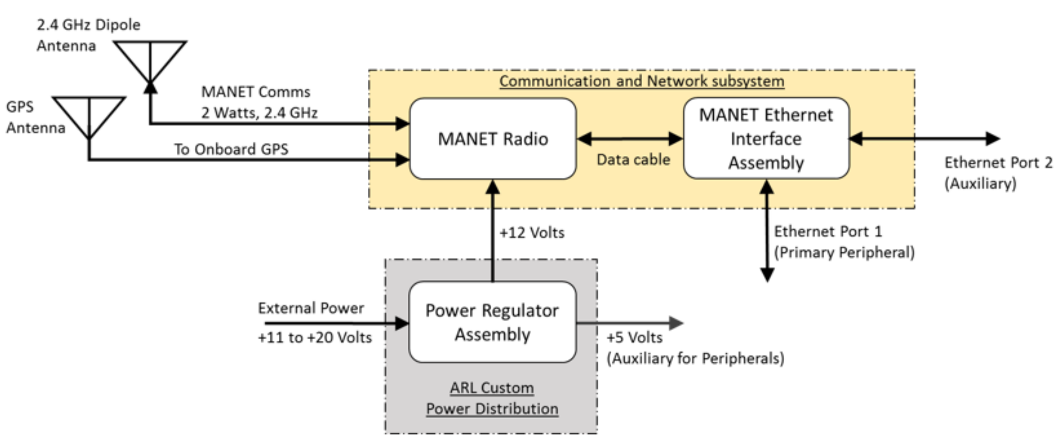

Fig. 5 Functional MANET back-end block diagram

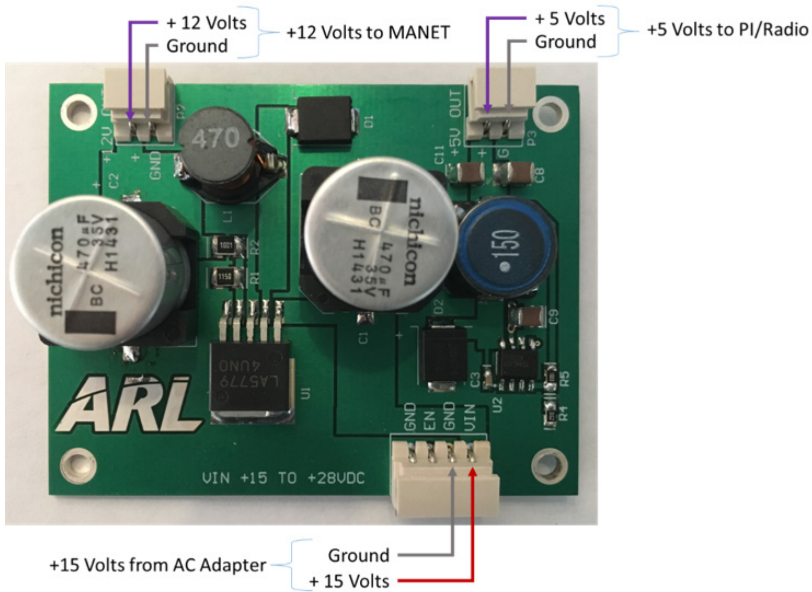

Fig. 6 Custom ARL node power supply implementation (see the Appendix for the schematic)

3.2 Source Hardware

The SDSS configured as a source (Fig. 7) was used to emit several test signals for the sensors detect and geolocate. The transmitted test waveform was controlled via the MANET, allowing the test coordinator the ability to quickly execute their test plan without leaving the command and control stations.

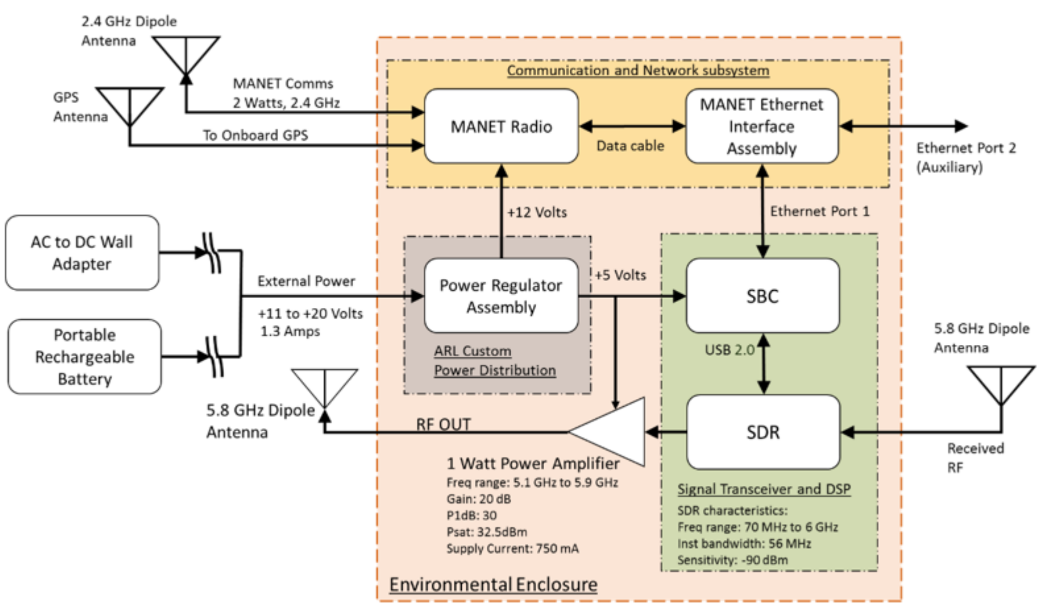

Fig. 7 Functional target node block diagram

The hardware consists of the MANET radio (Fig. 8) for communication between the test site controller located at the base node as well as to provide geolocation ground truth for the transmitter's location. A single board computer (SBC) serves as the interface between the test coordinator and the SDR (Fig. 9).

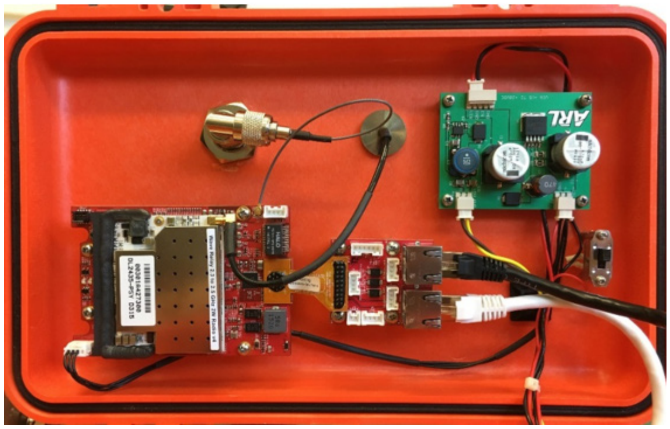

Fig. 8 MANET radio installed in the top half with the ARL buck switching power supply

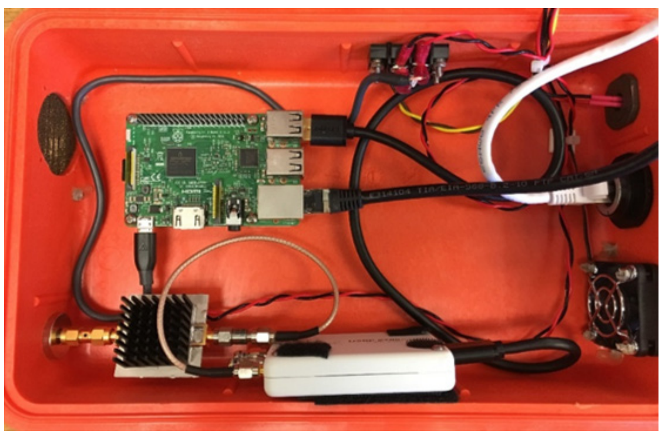

Fig. 9 SBC, SDR, and power amplifier installed in the bottom half

A medium-power (1-W) amplifier (Fig. 10) was used to provide adequate signal strength at the experiment test site. The amplifier used was chosen to operate at the 5.8-GHz ISM (industrial, scientific, and medical) radio band. As Fig. 11 shows, the simulated amplifier gain extends past our desired frequency of interest. Fig. 10 shows the simulated schematic that was used to generate the Fig. 11 data. An SMA (subminiature version A) connectorized 3-dB attenuator was placed at the input of the power amplifier to improve the match between the power amplifier and SDR (Fig 12). Figure 13 shows improvement to the power amplifier's S_{11} with the addition of the attenuator. The loss in input power to the power amplifier was compensated in the SDR without introducing any impedance degradation between the devices. Table 1 lists the source module generic bill of materials.

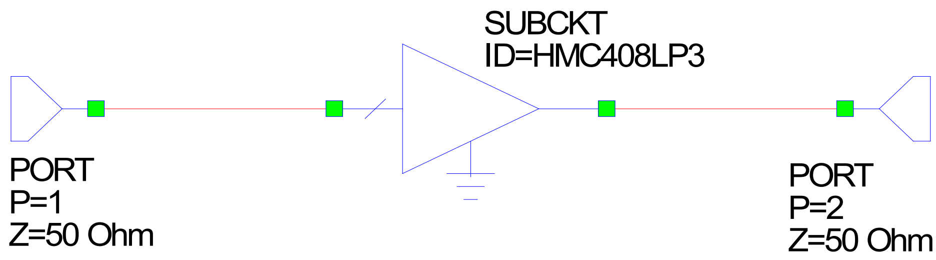

Fig. 10 Output amplifier simulated schematic

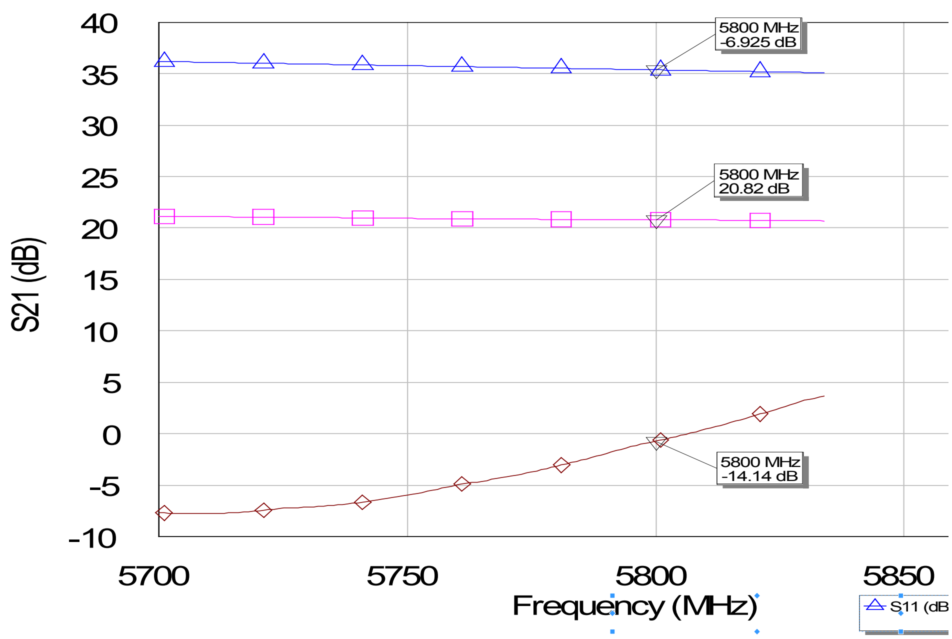

Fig. 11 Simulated S-parameters of the 1-W power amplifier used in the target node hardware assembly

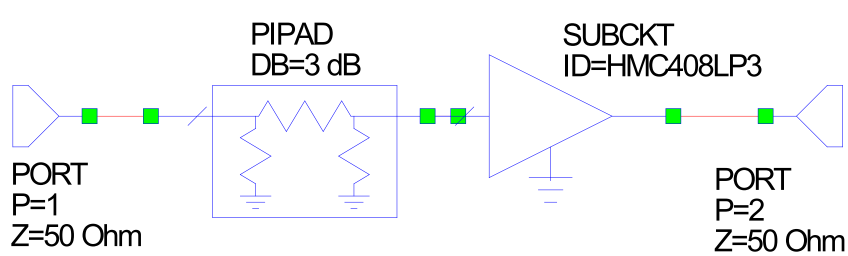

Fig. 12 Amplifier simulated schematic with 3-dB broadband pi attenuator at the input of the 1-W power amplifier

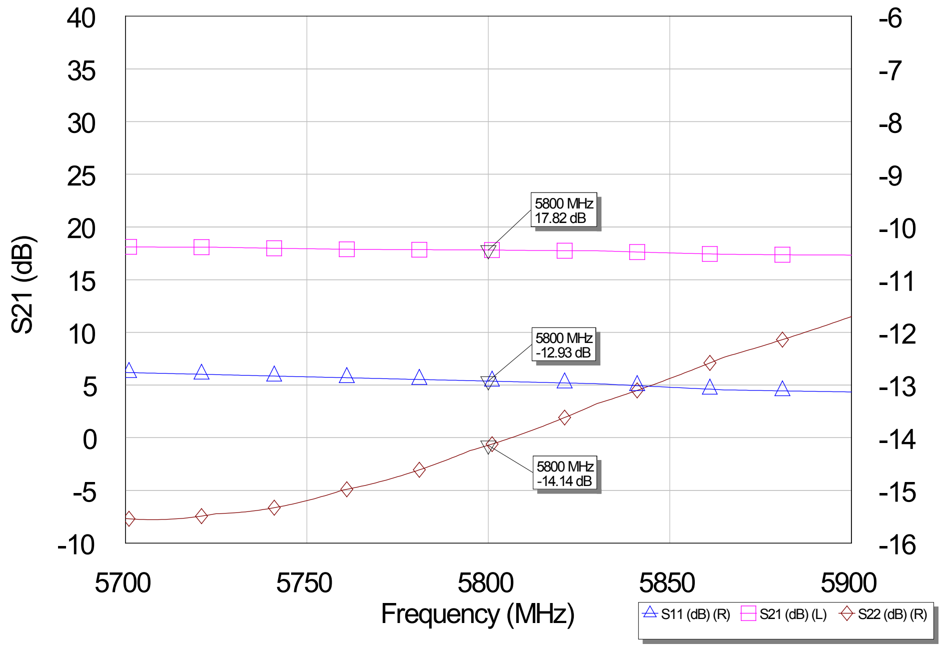

Fig. 13 Simulated S-parameters of the 1-W power amplifier with 3-dB pi attenuator at the input. The attenuator was added to increase the possible impedance mismatch between the output of the SDR and the input of the power amplifier.

Table 1 Source module generic bill of materials

Line item	Quantity	Description
1	1	MANET radio
2	1	MANET radio Ethernet adapter
3	1	SBC
4	1	SDR
5	1	1-W RF amplifier
6	1	5.8-GHz dipole transmit antenna
7	1	GPS cable
8	1	2.4-GHz dipole MANET communications antenna
9	1	MANET GPS antenna
10	1	Ethernet bulkhead
11	1	Power adapter
12	1	Power wall adapter
13	1	Power 12-V cable
14	1	Portable battery
15	1	N bulkhead to MCX (micro coax) pigtail
16	1	ARL switching buck power supply
17	1	ARL MANET power supply cable assembly
18	1	11- × 6- × 3-inch (length × width × height) enclosure

3.3 ARL Sensor Hardware Configuration

The SDSS module configured as a sensor (Fig. 14) consists of the same functional hardware components but without the power amplifier. The MANET, power supply, and SBC hardware were installed identically to the emitter modules, allowing easier fabrication of the SDSS nodes. These modules were used to detect and geolocate the emitters during the experiment. Table 2 lists the sensor module generic bill of materials.

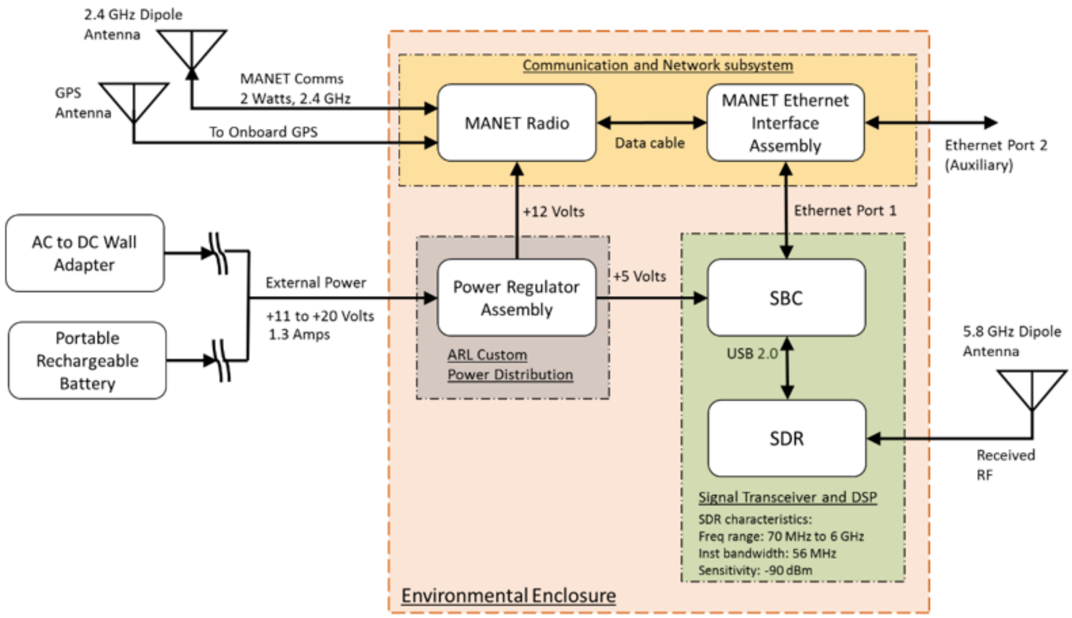

Fig. 14 Functional sensor module block diagram

Table 2 Sensor module generic bill of materials

Line item	Quantity	Description
1	1	MANET radio
2	1	MANET radio Ethernet adapter
3	1	SBC
4	1	SDR
5	1	1-W RF amplifier
6	1	5.8-GHz dipole transmit antenna
7	1	GPS cable
8	1	2.4-GHz dipole MANET communications antenna
9	1	MANET GPS antenna
10	1	Ethernet bulkhead
11	1	Power adapter
12	1	Power wall adapter
13	1	Power 12-V cable

Table 2 Sensor module generic bill of materials (continued)

Line item	Quantity	Description
14	1	Portable battery
15	1	N bulkhead to MCX pigtail
16	1	ARL switching buck power supply
17	1	ARL MANET power supply cable assembly
18	1	11- × 6- × 3-inch (length × width × height) enclosure

4. Conclusion

The SDSS module hardware and testbed has been successfully fabricated and used. These modules provided the required testbed to support the collaborative research effort between ARL and UND. This effort resulted in 2 ARL emitter modules, 4 ARL sensor nodes, and 15 UND sensor modules being fabricated and integrated in a field experiment at UND's White Field test site. The common hardware architecture described provides a unique dynamic testbed for further distributed collaborative research efforts using a variety of different sensors and sources.

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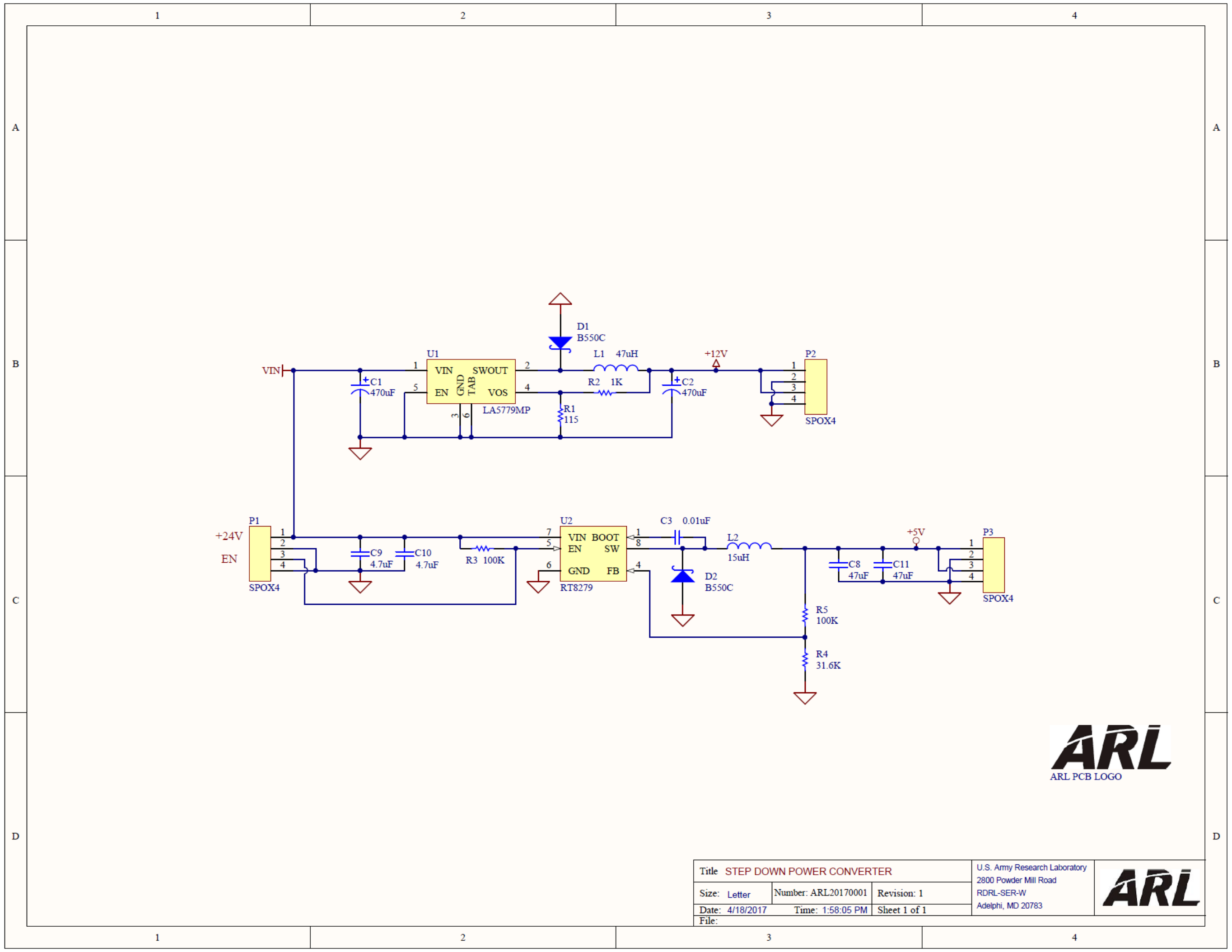
Appendix. US Army Research Laboratory Custom Step-down Power Supply Schematic



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B550C
L1 47uH
R2 1K
R1
115
C1
470uF
C2
470uF
+12V
P2
SPOX4
C9
4.7uF
C10
4.7uF
R3 100K
U2
VIN
BOOT
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SW
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D2
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List of Symbols, Abbreviations, and Acronyms

ARL	US Army Research Laboratory
COTS	commercial off the shelf
DPNC	data processing and network control
GPS	Global Positioning System
ISM	industrial, scientific, and medical
MANET	mesh ad hoc network
MCX	micro coax
RF	radio frequency
RSSI	received signal strength indicator
SBC	single board computer
SDR	software-defined radio
SDSS	software-defined sensors and sources
SMA	subminiature version A
UND	University of Notre Dame

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